CHAPTER 12: SOILS FIELD PROCEDURES USING THE SAND CONE PROCEDURE

Scope

In accordance with INDOT Specification 203.24(b), field density determination of soil compaction is made in accordance with either AASHTO T 191 (Sand Cone), AASHTO T 310 (Nuclear Gauge), or AASHTO T 272 (Family of Curves and One-point Proctor).

This section will detail the procedures for AASHTO T 191 **DENSITY OF SOIL IN-PLACE BY THE SAND CONE METHOD.** A detailed review of AASHTO T 191 should be accomplished at this time.

This procedure contains three very distinct and important sections.

- Section 3: Apparatus
- Section 4: Cone Correction and Bulk Density Factors
- Section 5: Procedure

The apparatus required for the Sand-Cone Method consists of a one-gallon jar, a detachable metal appliance, and a base plate. The metal appliance can be attached to the jar to allow the sand to flow from the jar during calibrations or density testing. The density apparatus and base plate are detailed in AASHTO T 191. A calibration container is also required for this test. The calibration container is used to determine sand density. The volume of the container is to be determined annually at the district lab in accordance with AASHTO T191. The volume of the container should be marked on the side of the container to an accuracy of 0.0001 cubic feet.

Prior to determining the bulk density of the sand and prior to conducting density tests, the technician must determine the mass (weight) of sand required to fill the large cone of the density apparatus and the accompanying base plate. This mass will be determined to the nearest 0.01 pounds and is referred to as the Cone Correction. Remember, the density apparatus and the base plate should remain together and not be interchanged with other devices without recalculating the Cone Correction. The Cone Correction is calculated daily on Form IT 625 (for soil), IT 625B (for Sand), and on Form TD 320.

The procedure for determination of the Cone Correction is detailed in AASHTO T 191 and is summarized as follows:

1. Fill the apparatus with the calibration sand and record the mass (weight) to the nearest 0.01 pounds
2. Place the base plate on a clean, level surface
3. Invert the apparatus onto the base plate and open the valve. This will allow the cone and the base plate to fill with sand.
4. When the sand stops flowing into the cone, shut the valve and weigh the apparatus to the nearest 0.01 pounds.

5. The difference between the full weight of the apparatus and the final weight after filling the cone is referred to as the Cone Correction.

Determination of the calibration sand density is a procedure also accomplished daily by the technician prior to conducting in-place density tests. The gradation of the calibration sand required for this test is included in the specifications in Section 203.24 (b). Sand complying with this specification will be furnished by the District Testing Department and a supply should be obtained when the density equipment is obtained. The determination of the calibration sand density is accomplished in accordance with AASHTO T 191 and recorded on INDOT Form IT 625 Daily Summary of Soil In-Place Density Tests, IT 625B Daily Summary of Sand In-Place Density Tests, or on Form TD 320 Daily Summary of In-Place Density Tests (+3/4 material).. These forms have a section titled Bulk Density of Sand along the right margin. This procedure is repeated daily and when a new bag of calibration sand is used.

A calibration container with a known volume is required to determine the Bulk Density of the calibration sand. By knowing the volume of the calibration container and the weight of calibration sand required to fill the container, the bulk density of the calibration sand in pounds per cubic foot may be calculated.

The process is detailed in AASHTO T191 Section 4 and is summarized as follows:

1. Fill the apparatus with the calibration sand and record the mass (weight) to the nearest 0.01 pounds.
2. Place the base plate on the calibration container.
3. Invert the apparatus on the base plate and open the valve. This will allow the calibration container and the large cone to fill with sand.
4. Shut the valve on the apparatus and weigh the apparatus to the nearest 0.01 pounds.
5. The initial weight of the apparatus minus the final weight and minus the Cone Correction is the weight of the calibration sand required to fill the container.
6. Divide the weight of the sand in the container by the volume of the container to determine the bulk density of the sand. The bulk density of the sand will be calculated to the nearest 0.1 pounds per cubic foot.

Remember that the apparatus, the base plate and the calibration containers may not be interchanged with other devices without recalculation of the above values.

Base Plate, Apparatus, and Calibration Container

CONTRACT NO. _____ PROJECT NO. _____ ROAD NO. _____ DATE _____ WEATHER _____

Field Test Number					
Location of Tests	Station				
	Reference to Centerline				
	Elevation or Lift Number				
Compacted Depth of Lift					
Method of Compaction					
No. of Passes with Roller					
Soil	1. Wet Wt. of Mat. from Hole & Pan (0.01 lbs.)				
	2. Wt. Of Pan (0.01 lbs.)				
	3. Moist Wt. of Mat. (M_{ws}) (0.01 lbs.) **line 1- line 2**				
	4. Dry Wt. of Mat. (M_{DS}) (0.01 lbs.) **line 3 /(1+(MC_T / 10**				
Sand Cone	5. Initial Wt. of Filled Apparatus (m_5) (0.01 lbs.)				
	6. Final Wt. of Apparatus & Sand (m_6) (0.01 lbs.)				
	7. Net Wt. of Sand (0.01 lbs.) **line 5 - line 6**				
	8. Wt. of Sand in Hole (0.01 lbs.) **line 7 - C_c**				
	9. Vol. of Test Hole (V_H) (0.0001 ft^3) **line 8 / D_B**				
10. Percent Moisture (0.1%) **MC_T or line 19 x 100**					
11. Proctor Optimum Moisture (0.1%)					
12. Dry Density of Material (D_D) (0.1 lb./ft^3) **line 4 / line 9 or Line 23**					
13. Proctor Maximum Dry Density (lbs./ft^3)					
14. Percent of Maximum Dry Density (1%) **(line 12 / line 13) x 100**					
15. Percent of Maximum Dry Density Required					
Test Remarks	Pass/Fail				
	Lab Sample No.				
	Material Description				

CONE CORRECTION (C_c)				
m_1	Wt. of Apparatus Filled w/ Sand (0.01 lbs.)			
m_2	Wt. of Apparatus & Remaining Sand			
C_c	Cone Correction (0.01 lbs.) = m_1-m_2			
BULK DENSITY OF SAND (D_B)				
m_3	Wt. of Apparatus Filled w/ Sand (0.01 lbs.)			
m_4	Wt. of Apparatus & Remaining Sand			
V_c	Volume of Calibration Container (0.0001ft^3)			
D_B	Blk. D. Sand (0.1 lbs./ft^3)= (m_3-m_4-C_c) / V_c			
% MOISTURE - ITM 506(1)				
W1	Wt. of Pan & Wet Soil (1g)			
W2	Wt. of Pan & Dry Soil (1g)			
W3	Wt. of Pan (1g)			
MC_T	% Moist.(0.1%) = ((W1 - W2) / (W2 - W3)) x 10			
+ No. 4 CORRECTION(2)				
16. Dry Wt. of + No. 4 Material (0.01 lbs.)				
17. % +No. 4 Mat. (P_c) (0.1%) **(line 16 / line 4) x 100**				
18. % - No. 4 Mat. (P_f) (0.1%) **100 - line 17**				
19. MC_f (0.001) **(MC_T - (0.02 x line 17))/line 18**				
20. Dry Density (D_d) (0.1 lbs./ft^3) **line 4 / line 9**				
21. D_f Denominator (0.01) **(line 20 x line 17)/162.24**				
22. D_f Numerator (0.1) **line 20 x line 18**				
23. Adj. Dry Den.(D_f) (0.1 pcf) **line 22/(100 - line 21)**				
Remarks:				

Note 1: ITM 506-Field Determination of Moisture Content of Soils used for all cohesive soils

Note 2: In accordance with AASHTO T 224-Correction for Coarse Particles in the Soil Compaction Test. Assumes a moisture of 2% and a specific gravity of 2.60

Signed _____

IT 625

CONTRACT NO. _____ PROJECT NO. _____ ROAD NO. _____ DATE _____ WEATHER _____

Field Test Number					
Location of Tests	Station				
	Reference to Centerline				
	Elevation or Lift Number				
Compacted Depth of Lift					
Method of Compaction					
No. of Passes with Roller					
Compacted Material	1. Wet Wt. of Mat. from Hole & Pan (0.01 lbs.)				
	2. Wt. Of Pan (0.01 lbs.)				
	3. Moist Wt. of Mat. (M_{WS}) (0.01 lbs.) **line 1- line 2**				
	4. Dry Wt. of Mat. (M_{DS}) (0.01 lbs.) **line 3 /(1+(MC_T /100**				
Sand Cone	5. Initial Wt. of Filled Apparatus (m_5) (0.01 lbs.)				
	6. Final Wt. of Apparatus & Sand (m_6) (0.01 lbs.)				
	7. Net Wt. of Sand (0.01 lbs.) **line 5 - line 6**				
	8. Wt. of Sand in Hole (0.01 lbs.) **line 7 - C_c**				
	9. Vol. of Test Hole (V_H) (0.0001 ft^3) **line 8 / D_B**				
10. Percent Moisture (0.1%) **MC_T or line 19 x 100**					
11. Proctor Optimum Moisture (0.1%)					
12. Dry Density of Material (D_D) (0.1 lb./ft^3) **line 4 / line 9 or line 23**					
13. Proctor Maximum Dry Density (lbs./ft^3)					
14. Percent of Maximum Dry Density (1%) **(line 12 / line 13) x 100**					
15. Percent of Maximum Dry Density Required					
Test Remarks	Pass/Fail				
	Lab Sample No.				
	Material Description				

CONE CORRECTION (C_c)				
m_1	Wt. of Apparatus Filled w/ Sand (0.01 lbs.)			
m_2	Wt. of Apparatus & Remaining Sand			
C_c	Cone Correction (0.01 lbs.) = m_1-m_2			
BULK DENSITY OF SAND (D_B)				
m_3	Wt. of Apparatus Filled w/ Sand (0.01 lbs.)			
m_4	Wt. of Apparatus & Remaining Sand			
V_c	Volume of Calibration Container (0.0001ft^3)			
D_B	Blk. D. Sand (0.1 lbs./ft^3)= (m_3-m_4-C_c) / V_c			
% MOISTURE - AASHTO T 255[1]				
W	Wt. of Original Sample (1g)			
D	Wt. of Dried Sample (1g)			
MC_T	% Moist.(0.1%) = 100(W - D) / D			
+ No. 4 CORRECTION[2]				
16. Dry Wt. of + No. 4 Material (0.01 lbs.)				
17. % +No. 4 Mat. (P_c) (0.1%) **(line 16 / line 4) x 100**				
18. % - No. 4 Mat. (P_f) (0.1%) **100 - line 17**				
19. MC_f (0.001) **(MC_T - (0.02 x line 17))/line 18**				
20. Dry Density (D_d) (0.1 lbs./ft^3) **line 4 / line 9**				
21. D_f Denominator (0.01) **(line 20 x line 17)/162.24**				
22. D_f Numerator (0.1) **line 20 x line 18**				
23. Adj. Dry Den.(D_f) (0.1 pcf) **line 22/(100 - line 21)**				
Remarks:				

Note 1: AASHTO T 255-Total Evaporable Moisture Content of Aggregate by Drying used for sand & B-Borrow sand.

Note 2: In accordance with AASHTO T 224-Correction for Coarse Particles in the Soil Compaction Test. Assumes a moisture of 2% and a specific gravity of 2.60

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IT 625b

CONTRACT NO. _____ PROJECT NO. _____ ROAD NO. _____ DATE _____ WEATHER _____

Field Test Number					
Location of Tests	Station				
	Reference to Centerline				
	Elevation or Lift Number				
Compacted Depth of Lift					
Method of Compaction					
No. of Passes with Roller					
Compacted Material	1. Wet Wt. of Material from Hole & Pan (0.01 lbs.)				
	2. Wt. Of Pan (0.01 lbs.)				
	3. Moist Wt. of Mat. (M_{ws}) (0.01 lbs.) **Line 1- Line 2**				
	4. Dry Wt. of Mat. (M_{DS}) (0.01 lbs.) **Line 3 /(1+(MC_T / 1**				
Sand Cone	5. Initial Wt. of Filled Apparatus (m_5) (0.01 lbs.)				
	6. Final Wt. of Apparatus & Sand (m_6) (0.01 lbs.)				
	7. Net Wt. of Sand (0.01 lbs.) **Line 5 - Line 6**				
	8. Wt. of Sand in Hole (0.01 lbs.) **Line 7 - C_c**				
	9. Vol. of Test Hole (V_H) (0.0001 ft^3) **Line 8 / D_B**				
10. Percent Moisture (0.1%) **Line 19 x 100**					
11. Proctor Optimum Moisture (0.1%)					
12. Dry Density of Mat.(D_D) (0.1 lb./ft^3) **Line 23**					
13. Proctor Maximum Dry Density (lbs./ft^3)					
14. Percent of Maximum Dry Density (1%) **(Line 12 / Line 13) x 100**					
15. Percent of Maximum Dry Density Required					
Test Remarks	Pass/Fail				
	Lab Sample No.				
	Material Description				

CONE CORRECTION (C_c)				
m_1	Wt. of Apparatus Filled w/ Sand (0.01 lbs.)			
m_2	Wt. of Apparatus & Remaining Sand			
C_c	Cone Correction (0.01 lbs.) = m_1-m_2			
BULK DENSITY OF SAND (D_B)				
m_3	Wt. of Apparatus Filled w/ Sand (0.01 lbs.)			
m_4	Wt. of Apparatus & Remaining Sand			
V_c	Volume of Calibration Container (0.0001ft^3)			
D_B	Blk. D. Sand (0.1 lbs./ft^3)= (m_3-m_4-C_c) / V_c			
% MOISTURE (AASHTO T255)				
W	Wt. of Original Sample (1g)			
D	Wt. of Dried Sample (1g)			
MC_T	% Moisture(0.1%) = 100(W - D) / D			
+ 3/4" CORRECTION(1)				
16. Dry Wt. of +3/4" Material (0.01lbs.)				
17. % +3/4" Mat.(P_c) (0.1%) **(line 16 / line 4) x 100**				
18. % -3/4" Mat. (P_f) (0.1%) **100-line 17**				
19. MC_f (0.001) **(MC_T - (0.02 x line 17)) / line 18**				
20. Dry Density (D_d) (0.1 lbs./ft^3) **line 4 / line 9**				
21. D_f Denominator (0.01) **(line 20 x line 17) / 162.24**				
22. D_f Numerator (0.1) **line 20 x Line 18**				
23. Adj. Dry Den.(D_f) (0.1 pcf) **line 22/(100 - line 21)**				
Remarks:				

Note 1: In accordance with AASHTO T 224-Correction for Coarse Particles in the Soil Compaction Test. Assumes a moisture of 2% and a specific gravity of 2.60.

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TD 320

Specification Sections 203.18 through 203.23 detail the methods of embankment construction with density control and without density control. Review these sections. Also the Frequency Manual should be reviewed for the frequency of tests on embankment construction. Embankment layers so granular that density testing is impractical may be controlled visually and documented as such on Form IT 625 or Form TD 320. Documentation of visually accepted lifts of embankment maintains a record of the method of acceptance of the lift for coordination with the frequency manual requirements.

With the calibration of the Bulk Density of the calibration sand and the Cone Correction Factor completed, the technician has all of the information necessary to begin in-place density tests. Using AASHTO T 191 and INDOT Form IT 625, the procedure for an in-place sand cone density tests on soil is as follows:

1. Fill the apparatus with calibration sand and record the weight on Line 5 of form IT 625.
2. Locate a representative area to accomplish the density test.
3. Remove any loose and uncompacted soil from the test site and level the area for the base plate to be seated.
4. Dig a hole into the soil through the hole in the base plate for the full depth of the layer being tested. Place the soil in a pan, weigh immediately, and record the weight on Form IT 625 Line 1 Wet Wt. of Mat'l from Hole & Pan. See INDOT Specification 203.24 for INDOT exceptions to AASHTO T191.
5. Reset the base plate over the test hole and invert the apparatus onto the base plate and open the valve to allow sand to flow into the test hole. When the sand flow stops, shut off the valve and remove and weigh the apparatus. Do not tap or vibrate the apparatus during this process. The weight obtained is entered on Form IT 625 Line 6 Final Wt. Apparatus and Sand.

Form IT 625 can now be completed through Line 9.

Determination of the soil moisture for Line 10 is obtained either with the AASHTO T 217 Speedy Moisture Tester or by ITM 506. ITM 506 is the preferred method for obtaining the moisture for soil. An area is included on Form IT 625 for calculation of the percent moisture of the soil using ITM 506.

The specifications refer to dry density requirements for soil compaction. The dry density is determined by dividing the dry weight of the soil removed from the hole by the calculated volume of the hole. When the soil contains material retained on the #4 sieve, the density will be adjusted to account for that material. The required calculations are detailed on Form IT 625. The dry density value will be determined to the nearest 0.1 pounds per cubic foot and is the actual in-place density of the soil. The specifications should be reviewed to determine whether the requirement is for 95 % or 100 % of the proctor value. On Form IT 625 line 13 list the target density from the laboratory test or from the one-point proctor test for the specific soil being tested. On line 11 list the optimum moisture content from the same report. Specifications will require passing results for both density and moisture content of the soil.

Care should always be exercised when selecting a target density and optimum moisture content from laboratory results from samples submitted to the district. Typically, representative samples of the soil submitted to the district are retained at the job site in small jars and compared to field test site soil. This comparison must be made by color, texture and plasticity to determine which soil samples more closely represents the layer being tested and thus which target density should be used. The one-point proctor is the preferred method to determine maximum dry density and optimum moisture content.

Form IT 625 may now be completed.

Note that there is an additional form IT 625B that is used for sand backfill or sand embankment construction. This form is required due to the requirement for the moisture determination for aggregate being accomplished in accordance with AASHTO T255. IT625 for soils requires ITM 506 for the moisture determination.

It is also often necessary to determine the density of coarse, granular material. Density for embankment layers constructed with sand may be determined using Form IT 625B, but coarse granular material must use Form TD 320. Some granular fill material, coarse aggregate size # 53, coarse aggregate size # 73, and some structural backfill (one inch and larger B-Borrow) require the use of Form TD 320.

The density process is the same as described previously with the following exceptions.

1. The percent moisture must be obtained using AASHTO T255 and drying the entire sample taken from the test hole.
2. The sample removed from the test hole must be weighed, dried, and then sieved through a ¾ inch sieve. The weight of the dry plus 3/4 inch material must also be obtained and is recorded as Dry Weight of +3/4 Material on Form TD 320. This dry weight of +3/4 material is used to correct the field density of the material being tested based on an assumed moisture content of 2 percent and an assumed specific gravity of the +3/4 material of 2.60. Remember that the laboratory proctor for aggregate material is obtained on the minus ¾ material only and using the above procedure will correct the field in-place density so the field test results also represent only the minus ¾ material.
3. The target density and optimum moisture content must be obtained from the District Materials and Tests Soils laboratory.

The Form TD 320 contains the procedures for cone correction, bulk density of the sand, percent moisture, and plus ¾ correction required formula to complete the calculations for the in-place density of the granular material. A sample form TD 320 is included in the appendix of this manual.

It should be noted that the specifications Section 203.23 allows for the moisture content of granular materials to be “several percentage points below optimum”. This means that dry density must be obtained as required, but the moisture content obtained in accordance with AASHTO T255 is not required to be within +1 and -2 percent of optimum for the lift to pass specified dry

density. Several percentage points below optimum has been interpreted to be no less than 50 percent of the optimum moisture content as shown on the laboratory tested sample.

It is not recommended to attempt to salvage and reuse the sand from the test hole. The salvaged sand may contain soil from the hole and the mixture of salvaged calibration sand and soil from the test site will change the sand bulk density and will affect the volume calculations and the Cone Correction.